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ART. V. — THE COAST OF EGYPT AND THE SUEZ CANAL.

IT is with the consent of Professor Peirce, the Superintendent of the Coast Survey, that I offer, in advance of an official report, selections from notes compiled in a recent professional visit to Egypt. I have been moved to do this by the thought that at this time, when public interest is somewhat drawn to the subject of the Suez Canal by the approach of the date of its formal opening, the leading features of this great work, set forth, however crudely, by one who has made a regular inspection of it, under authority from M. Lesseps, may be of interest to the general reader. The construction of this canal has added some new features to our knowledge of the geography of Egypt, and opens anew the problems presented in the physical history of the delta of the Nile.

Lower Egypt, " the gift of the Nile," has been regarded by most authorities, ancient and modern, as a territory reclaimed from a gulf or arm of the Mediterranean Sea, and not as a deposit superimposed upon the sands of the desert.*

The manner in which the sediments of rivers reclaim territory from the sea differs according to the degree of exposure at the embouchures. If the river empties into a great basin, the mud elevates the bottom of the latter pretty uniformly over a large area; but if it empties into the ocean, the waves break up the outflow, and cause an abrupt deposit, so that only the lightest material — that which is mechanically mixed with the river water, rendering it turbid — actually escapes into the sea.† In the first case the displacement is caused by a nearly vertical accumulation, and in the second by a horizontal encroachment. The Alabama discharges itself at the head of a sheltered bay, and we find for many miles beyond the uncertain shore-line of its delta a submerged bank of mud.* The Ganges and the Mississippi, on the other hand, push out long moles of earth against the waves of the sea.† The history of the harbor of Greytown illustrates both of these conditions. Formerly it was an exposed bend in the coast, at the head of which the San Juan River made a bold delta. By the gradual advance of Point Arenas this bend took the form of a bight, and finally became a lagoon. It was not, however, until the shelter from the waves was made complete, that a general elevation of the bottom of the basin commenced.‡

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* Herodotus, Book II., repeats this theory, which he learned of the priests of Egypt; and recent authors, like Dolomien and L. Elie de Beaumont, accept it fully. Sir Gardner Wilkinson takes the opposite view.

† For the character of deep-sea deposits, see "Law of Deposit of the Flood-Tide," by Lieutenant Charles H. Davis. Smithsonian Contributions, 1851.

Exposed deltas are usually bordered by sands — the residuum from the long-continued *sifting* action of the waves. These sands, in tideless seas, usually form an apron which is scarcely interrupted by navigable channels. The delta of the Danube offers an example of this class. In seas subject to considerable tides, the bordering sands are broken into slender banks, between which navigable channels occur. The Ganges and Burrampooter construct, at the head of the Bay of Bengal, the most remarkable delta of the latter class. The Mississippi delta, visited by a small diurnal tide, holds a somewhat intermediate position between these two classes, and advances its mud so rapidly upon the sea that the sand is not thoroughly disintegrated from other deposits. The Nile delta belongs to the tideless class. In view of its very slow progress, and of the exposure of its coast to prevailing winds from the north, the sands along its border, and the sand-bars at the mouths of the river, seem to offer no anomalies.

The accomplished L. Elie de Beaumont evidently entertains the notion that the sandy border of Egypt is a formation antecedent to the river delta; that it was a "*cordon littoral*," separating a gulf or lagoon from the Mediterranean, within the shelter of which the Nile has made a *homogeneous deposit of mud.* He says, indeed, that he believes the present outlets of the Nile are the first that have ever discharged their waters directly upon the sea. He cites the testimony of classical history to strengthen this statement, as showing that none of the seven ancient branches of the Nile sensibly emptied directly upon the sea; but that their waters reached the Mediterranean only after traversing the lagoons. When we consider that these lagoons, so vast in superficial area, are but thin sheets of water, whose beds lie but little below the level of the sea, the testimony loses its significance. No one, looking from a physical point of view at a chart of the Bay of Bengal, could say that the shore-line of the Sunderbunds is the boundary of the delta of the Ganges. On the contrary, he would point to the bold extremities of the great submerged moles of sand and say, "Here the river suddenly enters the sea," — more than twenty miles below its "*sensible*" mouths.

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* The rivers of China distribute their mud over the bed of the shallow and sheltered Yellow Sea without forming visible deltas.

† I am informed by Major-General Humphreys, that the Mississippi bars advance after the manner of submerged dunes; by the rolling of grains of sand up a long rear slope and down a steep fore slope.

‡ For the first complete history of the formation of a lagoon, see "Report of the Committee of the National Academy on Greytown Harbor, Nicaragua." 1866.

The littoral sandy cordon is a physical feature which Beaumont discusses at length in his descriptions of various countries, and he everywhere regards it as due to external causes, — to the waves and currents which abrade the projections of the coast, and drive the sands across the indentures of the shore. Many *hooks*, bights, and even lagoons have fallen under my own observation, which I know to have been formed in this manner. The instance of Sandy Hook is one in point. It is rapidly extending, under the action of the waves, which deposit at its extremity material torn from the New Jersey coast in the neighborhood of Long Branch. The case of Greytown, which I have already referred to, is similar and more perfect. But the sandy shore of Egypt does not appear to me to belong to this class of phenomena. I see no reason to believe that it existed before the outflows of the Nile, or that it has been formed under the action of external forces. Its form, curving outward from the general trend of the coast, indicates, not the action of the waves in front, but of a force in the rear. Upon our own coast we find the slender "littoral cordons" which separate lagoons from the ocean gradually moving in towards the continent; and, in the instances I have cited, of Sandy Hook and Greytown, the drifts of sand have been bent inward as they advanced. It is difficult to conceive of any external forces which could have formed a convex coast like that of the Nile delta. In digging the canal through the beach at Port Saïd the pure sand was found to be but a superficial border. At about seventeen feet below the mean level of the sea (which is about the limit of wave action) a material is found apparently corresponding with that excavated, further on, from Lake Menzaleh.

I fall back, then, upon the primitive idea, which every one entertains on first looking upon a map of Egypt; viz., that a bank of mud has projected itself upon the sea. I have been confirmed in this view by an inquiry into which I have been led by my surprise at finding in all the authorities upon Egypt a statement that Cape Bourlos, midway between the present outlets of the Nile, is the most advanced point of the delta, — which it certainly is not. Its geographical position — more seaward and in higher latitude than the adjacent coast — has led to this error; but if we look at this shore as *a creation of the Nile* we are undeceived. We discover that the coast forms very nearly the arc of a circle of which the delta is a sector; that Cape Bourlos is not as distant from the centre as the present mouths of the river; and that the waters of the Nile are performing longer journeys to reach the sea by the Rosetta and Damietta outlets than by any other routes we could project within the sector.*

Is it unreasonable to suppose that the Nile has changed its outlets whenever these have become so prolonged as to present great resistance to its floods, and that before the occupation of the country by dike-builders the river was in some degree free to seek the shortest route to the sea, especially in periods of inundation? The conclusion is forced upon my mind that, in ages past, the coast-line, while slowly advancing upon the sea, must, in its general sweep, have oscillated about the arc of a circle, of which the centre was somewhere in the main artery of the great floods.

My search for this central point led to a curious result. I took a string and pencil, and described upon Linant's chart successive circles, continually altering the position of my centre and the length of my radius, till I was satisfied that I had plotted the arc which best conformed to the general sweep of the coast from the Tower of the Arabs to Peluse. Watching my arc, I had not perceived in what direction I had been shifting my centre, but now, lifting my finger to mark the point, I discovered beneath it the Pyramids of Gizeh! Subsequently I plotted the Great Pyramid upon the recent coast-chart of the Suez Canal Company, and found my previous result confirmed.* Situated upon the last rock that confines the floods of the Nile, this structure occupies a more important physical position than any other artificial object upon the face of the earth, since it is the centre from which radiated the waters of the river, and from which, from age to age, the coast may be supposed to have advanced in concentric arcs. With no predisposition to believe in the scientific purposes of the pyramid-builders, I nevertheless cannot help thinking that, if there ever existed a comprehensive and economical system of irrigation in Lower Egypt, this initial point must have been to the engineer one of primary importance.†

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* One of the Greek authorities cited by Rawlinson describes Egypt as shaped like a battle-axe. The Arabs call it *Er Rif,* the pear.

To return to the subject under discussion, I must remark finally that the hypothesis of a pre-existing sheltered bay or grand lagoon is not necessary to explain the absence of sands upon the delta, since these sands do exist in great masses to bear witness of the past. About eighteen miles north of Cairo, surrounded by fertile lands, there is a pair of "sand islands," each of which has an area of several square miles.* These islands are elliptical in form, with major axes lying respectively north-northeast and north. Between them there is a strait of arable land about as broad as the Nile. Again, about thirty miles north of Cairo, between the two arms of the Nile, but much nearer the Damietta, occurs another pair of islands of more eccentric forms than those previously mentioned, but of nearly the same area. The strait between these (having a course north-northwest) is broad enough for the main river, and is occupied by a slender branch of it. If I produce the axes of the two straits I have mentioned, they meet in the broad portion of the Nile just above the bifurcation.† These traces of ancient water-ways lie near the head of the delta, where the velocity of the outflow must have been very much greater than at the present outlets. It is for this reason, probably, that we find the straits, as I have called them, radiating from a point in the main stem of the Nile. This lends support to the theory that there was no pre-existing desert, because dunes of such elevation, if anterior to the outflow of the river, would have deflected the streams from their free course.

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* The latitude of the Great Pyramid (the more important element for this) was not long ago carefully re-determined by Professor Smyth, Royal Astronomer of Scotland. The longitude I took from Linant. I required my circles, as I drew them, to touch the outer rocks (contemporaneous formations) at Alexandria and Abou-Kir; to clear Cape Bourlos (which has, according to Beaumont, slightly retrograded under the action of the sea), and to fall in with the shore at Peluse, where the beach under the action of waves from the westward has advanced fifteen hundred feet since the days of Strabo, — i. e. since the closing of the ancient Pelusic and Tanitic branches. Although my arc is over one hundred degrees, I do not pretend to distinguish between the Great Pyramid and its immediate neighbors of the same group.

† Since writing the above, I have discovered the following passage in Girard (of the French expedition): "The coast of Egypt, from Alexandria to Peluse, presents a great curve, turning its convexity to the north, upon which the point of Abou-Kir and the two outlets of the Nile are salients. Precisely in the middle of the distance which separates them (the outlets) we find Cape Bourlos, the most northern point of Egypt, situated upon the same meridian as the pyramids." Except the allusion to Abou-Kir, this is correct.

Sir Gardner Wilkinson observed the sands in the deposits of the Nile, but he says, "As marine productions have not been met with in boring to the depth of forty feet in the delta, it is evident that its soil was deposited from the very first on a space already above the level of the Mediterranean." ‡ This is a very curious statement. The borings must have been confined to a very small space near the head of the delta, because it is no exaggeration to say, that of the soil of Lower Egypt not covered by dunes not one-eighth part is elevated forty feet above the reach of the sea, nor one half of it ten feet. Dr. Clot-Bey, who spent the larger part of his life in Egypt, not only states explicitly that the Nile bears sand along its bed all the way to the sea, but that beneath the fertile soil of the delta petrifactions of marine animals are found.§ The Nile has so often shifted its course through Lower Egypt, that it may have replaced by new deposits much of the original soil, and for great depths. In this way also the finer sands of the underlying sea-bed may have been swept to the front. It is probable that the desert, before its emergence from the sea, was a horizontal plane like the Bahama Banks. If the relative elevations of land and sea were altered twenty-four feet by the uplifting of the former, the Bahama Banks would expose many thousands of square miles of surface sensibly level, and still in the midst of this area would appear gulfs not unlike the Red Sea, except that they would be much deeper and have bolder fore shores.

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* *Île de sable au milieu des terres*" is the designation upon the Canal Company's map of the Isthmus (1866).

† In the *Batn-el-Baquarah* (cow's belly).

‡ Rawlinson's Herodotus.

§ *Aperçu Général sur l'Égypte.*

I have entered into this long discussion because, although there are evidences that Lower Egypt has been, in great part, reclaimed from the sea, it is highly improbable that there was originally in its place a narrow gulf, as Herodotus concluded, like that at Suez, and especially that this gulf was protected by a sandy cordon as Beaumont supposes. Whether we take for measure the very slow advance of the shore-line of the delta upon the Mediterranean, or the vertical accumulation upon the borders of the Nile, we are carried back to a very remote period, — perhaps as far as the naturalist would be who should examine the shells strewn here and there over the adjacent desert sands. But if the ancient portion of the delta was formed during the period of general emergence, a change of regimen has occurred, for this uplifting ceased many thousand years ago. The traces of high and low water levels in the basins of the Lacs Amers, which have been essentially dry through the entire historical period, and the beds of shells along their shores, correspond in vertical position with the similar phenomena renewed daily upon the Red Sea at Suez.*

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* Some of the shells which I picked up were as fresh and unbroken as those cast upon our shores by last winter's storm, and the ridges caused by the wash of high and low waters — familiar objects of study to me — gave the same range of tide that is now observed in the Red Sea at Suez. Here is the testimony of thousands of years to be counted for nothing in the geological chronology, for no change has occurred to mark this lapse of time. The solemn impression of the death-like immobility of nature that I received in this desert I afterwards recalled, as I witnessed an eruption of Vesuvius and felt the earth convulsed beneath my feet.

The portion of the delta shore lying west of Abou-Kir has a rocky border, at some points elevated twenty feet. I recognized it as a range of calcareous dunes consolidated. But six months before I had examined a similar formation in progress on Salt Key, in the Bahamas, where the dust of shells ground up by the sea is blown into dunes, and subsequently converted into compact rock. To the east of Abou-Kir the shore is sandy, and generally low, like the north shore of the Gulf of Mexico.

The sands of the Egyptian beaches are remarkably fine, and in this respect unlike those of littoral cordons, where all but the coarsest sands are sifted out by the sea, — and quite unlike the desert sands, which are of all sizes from large pebbles downwards. No one who compares these sands with those of other coasts can doubt that they have been transported by a more gentle agent than the waves of the sea, or can fail to conclude that they have been swept down by the river along its bed.

The Mediterranean, although sometimes very rough, and often an uneasy sea, is not, like the Atlantic, traversed continually by a long roll or "ground swell." The waves on the coast of Egypt are short and sharp, and the breaker upon the shore is generally of short reach. There is not that great advance and recoil which we observe in the seas that roar along our shores. In the neighborhood of Port Saïd I noticed that the sand along the water-line was beaten down quite hard, — as I have often observed it along our inside beaches, — and not like the sands of ocean shores. As winds from the northwest prevail, and as the greater body of water lies in that direction, the prevailing set of the sea is also from that quarter, and the movement of the sands of the coast is toward the east. The easterly current which prevails all along the southern portion of the Mediterranean does not, as far as my observation goes, possess scouring power affecting the shore-line.

To the west of Abou-Kir there seems to be little sand travelling along the rocky shore, but to the east, beyond the river mouths, the amount is considerable. Cape Bourlos yields a little to the wear of the sea, and during floods the bars of the Rosetta and Damietta give way, and distribute part of their sands along the shore. It has been observed at Port Saïd that the sands arrested by the west mole accumulate more rapidly immediately after the river floods. The circumstantial evidence is strongly in favor of regarding the Nile as the direct or indirect source of the sands upon the Egyptian coast. The very careful observations which have been made upon the Mississippi show that in the earthy matter travelling upon the river bed a considerable portion of sand appears, and that as this matter approaches the sea the proportion of sand to aluminous earth increases, so that at the outer bars, where the sifting action of the waves is fully experienced, the material is almost wholly sand.*

I have spoken of the Egyptian coast as somewhat approaching in form the arc of a circle. If, within this, I draw a concentric arc at a distance of about twenty-one miles, I enclose between the two the lagoon district of the delta. In this district the average elevation of the soil due to the deposit of the Nile is about that of the Mediterranean Sea. Of course I do not include the drifts of sand blown back from the coast. The lagoons themselves, although conspicuous features upon a topographical map, are really very slight depressions below the sea level, and therefore have no physical significance in a study of the coast. In the beds of old river-courses channel-ways are still found traversing these lagoons which are deep enough for small craft in the dry season.

It is remarkable that, notwithstanding the abundance of marine *débris* along the route of the canal, it has not yet been shown that the Red Sea and Mediterranean were ever connected. The distinct fauna of the two seas have been followed to points within a dozen miles of each other, but are nowhere found mingled.† As the two seas preserve at the present time nearly the same mean level, it is evident that no open passage could now be maintained by natural scour, since the alternating north and south currents caused by the tides would be equal and opposite.

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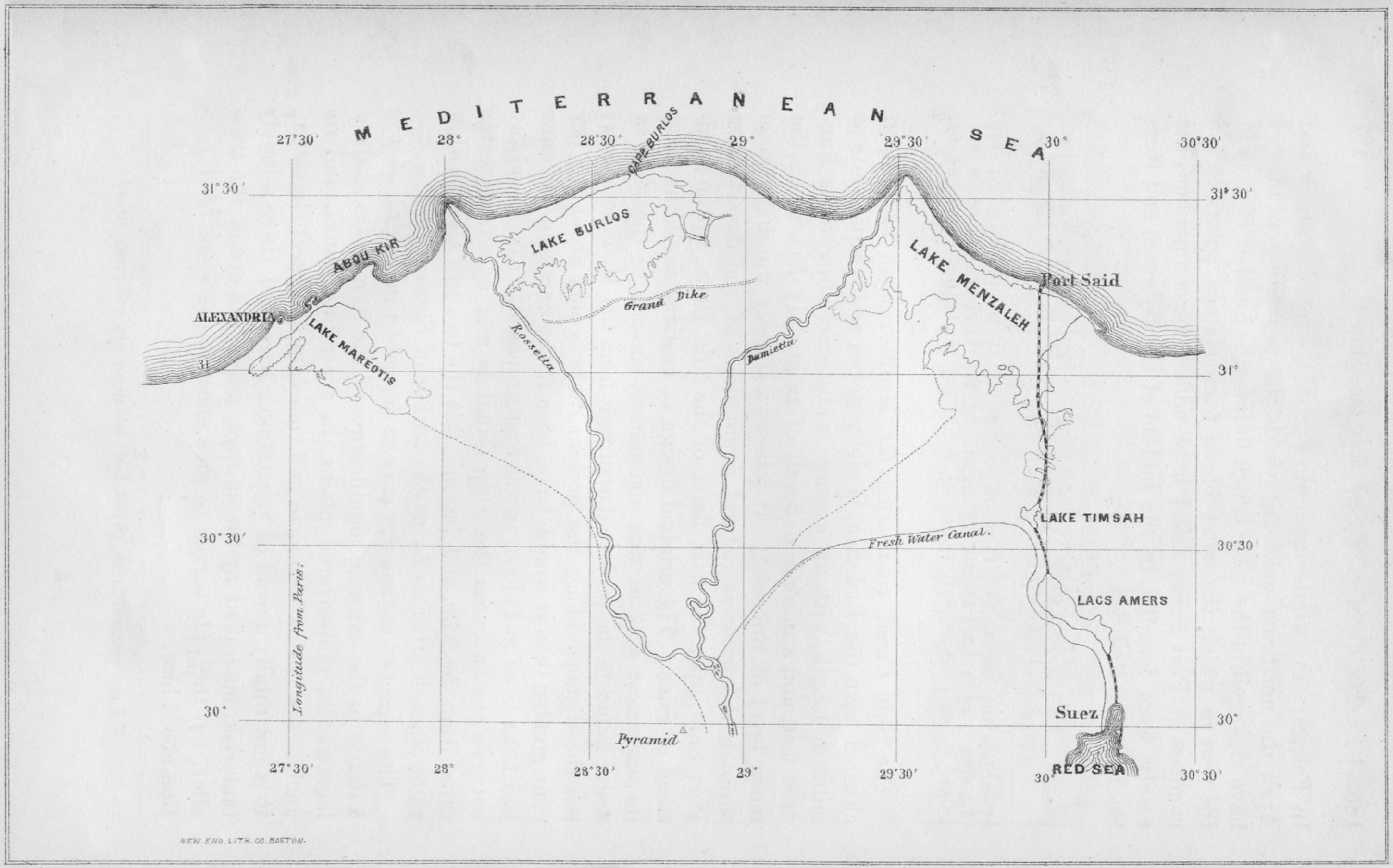
* See Report of Humphrey and Abbot on the Mississippi River, p. 446, and Appendix, p. x.

† Testimony of M. Laurent, cited in *L'Isthme de Suez,* August, 1868.



NEW ENG. LITH. CO. BOSTON.

To any one who has followed the discussions of Halley and others upon the phenomena of the Mediterranean, and has been convinced that the inflow at the Straits of Gibraltar is requisite to supply the loss sustained by evaporation, I offer the problem of the Red Sea, lying among thirsty deserts in the tropics, with scarcely any fresh water supply either from rivers or rains, with nearly the same level as the Mediterranean, and with no inflow at Bab-el-Mandeb to indicate that it is lower than the Indian Ocean. The recently perfected levellings across the French Empire show that the Mediterranean at Marseilles is three and a quarter feet below the Atlantic at Brest.*

I offer the suggestion that upon the open sea-coast the observed mean level must be higher than the true level of the ocean, because the swell from the ocean is always moving shoreward, and on reaching shallow ground has a real motion of *translation*, so that water is accumulated upon the coast; and because the winds which most affect the elevation of the water along the coast are those which blow from seaward, and these also accumulate the water. The sea is sheltered from land winds, especially in the shallow zone along the shore where their effect would otherwise be greatest. The Atlantic coast of Europe is a lee shore through the greater part of the year, and perhaps the difference of level between its waters and those of the Mediterranean may be wholly or in part due to the littoral accumulations I have described. It is evident that the Atlantic generally is not higher than the Polar Sea, the Pacific and the Indian Oceans, because permanent currents set southward from Baffin's Bay, eastward round Cape Horn and westward round the Cape of Good Hope.

That the comparative densities of different partially enclosed seas may be seen, I offer the following table of specific gravities: —

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* *Cours de Travaux maritimes, professé par M. Chevallier, Ingénieur-en-chef de Ponts et Chaussées.* Of course we cannot conceive of a slope as great as three feet and a quarter in the Straits of Gibraltar, since the permanent inflowing current (deducting the tide) is only two to three miles per hour. The Red Sea is actually a few inches higher than the Mediterranean: perhaps the *total* slope through the Suez Canal will be as great as that through the Straits of Gibraltar. It is generally believed that a counter-current exists below the surface of the Straits, but the evidence of this is not of a good kind. The same notion prevailed relative to the Gulf Stream in the Strait of Florida till my observations disproved it.

Red Sea	1.0308 (Suez Canal Engineers.)
Mediterranean . . .	1.026 to 1.029 *
North Atlantic . . .	1.0265 to 1.0288 †
Yellow Sea	1.023
White Sea	1.019
Baltic Sea	1.015
Black Sea	1.014

It will be observed that the Red Sea heads the list. I will mention, before quitting this subject, that recent inquiries indicate a slight decrease of salts for great depths in the ocean.

Not only through the Straits of Gibraltar, but all along the African coast far into the Levant, runs an easterly current, which is described as having sometimes a velocity of three or four knots off the coast of Egypt. ‡ In the immediate neighborhood of Port Saïd the observations taken since the canal was commenced, which I inspected, showed only occasional velocities as high as one knot, — the mean scarcely exceeding half a knot. Easterly winds, when violent, reverse the stream all the way to the Atlantic.

Although the coast of Egypt is low, with little to distinguish the land-fall, it has but few outlying shoals. There are no dangers beyond the general sweep of the twelve-fathom curve, which is nowhere more than ten miles from shore. The fifty-fathom curve lies but six miles off Alexandria, fifteen miles off the mouth of the Rosetta, twenty-one miles off Cape Bourlos, and twenty-one miles off the mouth of the Damietta. The lead is therefore a safe and indispensable guide to the navigator. The Egyptian Government is about to place first-class lights at Abou-Kir, at Cape Bourlos, at the mouth of the Damietta, and at the extremity of the great mole at Port Saïd.

The winds upon the coast of Egypt are principally from the northwest quadrant from the middle of May to the middle of October. They are variable in November, but in December and January winds from the southwest quadrant predominate.

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* The smaller quantity is from observations by the Suez Canal engineers. The larger from Dr. Marcet. (Phil. Trans., 1819.)

† The smaller quantity is from my own observations in mid-ocean, the larger from Dr. Marcet. Those that follow are all from Dr. Marcet.

‡ *Considérations Générales sur la Mer Méditerranée, par A. le Gras.* I presume these estimates are exaggerated.

In February the winds are again variable, while in March and April the northeast quadrant yields the prevailing winds. I have arranged in the table which follows the number of days in the year in which the wind blows from sixteen points of the compass at Port Saïd; and I have added, for comparison, the results from Ismaïlia, in the middle of the Isthmus, and from Suez, on the Red Sea.

Direction.	Calm.	N.	NNW.	NW.	WNW.	W.	WSW.	SW.	SSW.	S.	SSE.	SE.	ESE.	E.	ENE.	NE.	NNE.
Port Saïd	$10\frac{1}{2}$	$63\frac{1}{2}$	$30\frac{1}{2}$	69	$14\frac{1}{2}$	29	$10\frac{1}{2}$	36	$8\frac{1}{2}$	14	$4\frac{1}{2}$	9	$1\frac{1}{2}$	$10\frac{1}{2}$	5	34	$14\frac{1}{2}$
Ismaïlia	$4\frac{1}{4}$	$141\frac{2}{3}$	$38\frac{1}{6}$	$28\frac{1}{6}$	$24\frac{1}{3}$	$37\frac{1}{2}$	$3\frac{1}{4}$	$3\frac{5}{6}$	$3\frac{1}{12}$	$2\frac{1}{2}$	$3\frac{1}{2}$	$2\frac{1}{4}$	$3\frac{5}{6}$	$5\frac{3}{4}$	$6\frac{1}{2}$	9	47
Suez	82	$66\frac{2}{3}$	$79\frac{1}{4}$	$80\frac{1}{2}$	$3\frac{1}{4}$	10	$3\frac{5}{6}$	9	$3\frac{5}{6}$	$12\frac{1}{12}$	$2\frac{1}{4}$	$1\frac{5}{6}$	$0\frac{1}{6}$	$0\frac{2}{3}$	$0\frac{1}{3}$	$2\frac{3}{4}$	$6\frac{1}{6}$

The Ship Canal, connecting the Mediterranean by an open channel with the Red Sea, is eighty-seven and a half nautical miles in length, with an average width exceeding three hundred feet, and a minimum depth of twenty-six feet below the mean level of the sea.* It follows a slightly winding course through the greatest natural depressions of the desert from Port Saïd, upon the east flank of the Nile Delta, to the roadstead of Suez. The original design of crossing the Isthmus at its narrowest section was abandoned, because of the shallow water found in the projected approach from the Mediterranean; but the distance along the present route is only about ten per cent greater than it would have been if the northern entrance had been fixed at Peluse, as was first proposed. About midway between the two seas the Ship Canal is met by a fresh-water canal from the Nile, and beyond this the two run along within sight of each other as far as the harbor of Suez.

The aspect of the country may be described in a word, — it is a *desert* in the extreme signification of the term. Its shallow lagoons, its flint-covered plains, its travelling dunes, and its ancient sea basins belong to and complete its desert character. It is not totally devoid of vegetation; here and there a lonely tamarisk, magnified by the mirage, meets the eye of the traveller, but this only serves to give effect to the scene of desolation about him.

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* I use nautical miles (6,086 feet) whenever not otherwise stated.

The climate is healthy and agreeable. Although the sands heat up occasionally to 130° Fahrenheit, the extreme summer temperature of the air in the shade does not exceed that of Boston, reaching 95° at Ismaïlia last August. The summer temperature at the central station just named has a mean of 81°, the autumn of 67°, the winter of 59°, and the spring of 72°. The summer nights are cool, and there is nearly always a refreshing breeze. The heat of summer days brings with it no lassitude, for the air is still invigorating and delightful to breathe. Sunstrokes occur among those who refuse to wear proper covering, but the turban, or a woollen shawl thrown over the head and shoulders, is an effectual protection.

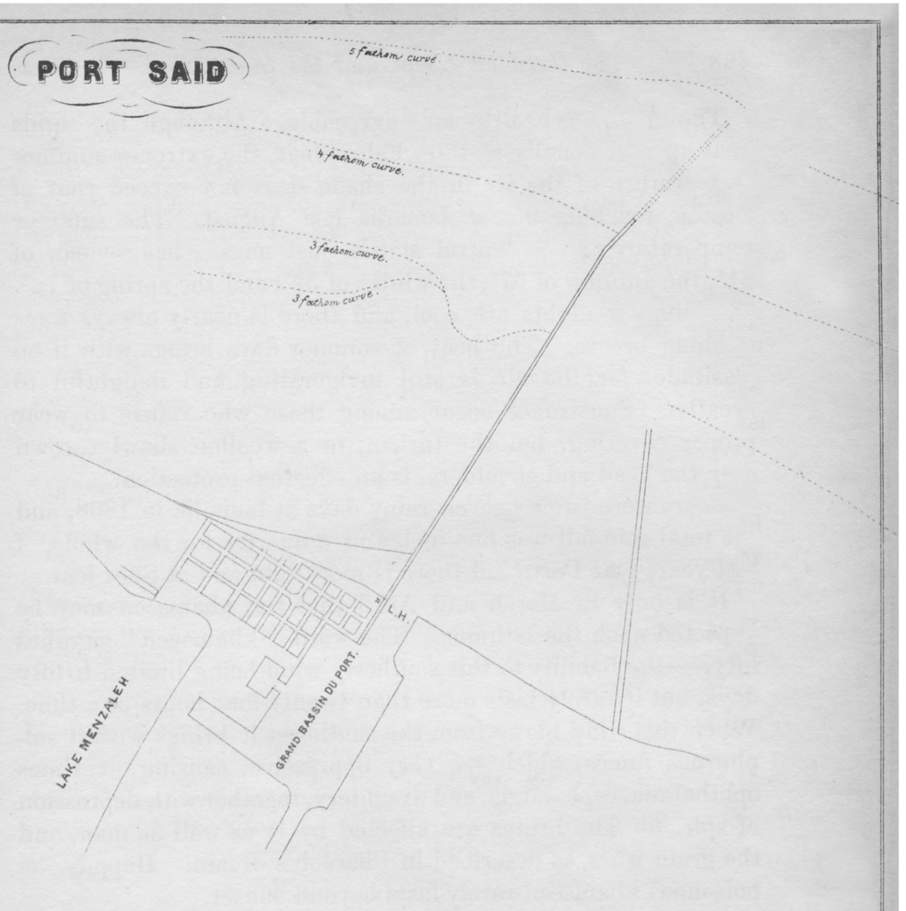
There were twenty-seven rainy days at Ismaïlia in 1868, and the total rain-fall was one inch and a quarter for the whole of last year. At Port Saïd there is more rain and at Suez less.

It is only in March and April that the khamseen may be expected upon the Isthmus. The word "khamseen" signifies fifty, — the liability to this southerly wind being limited to fifty days, but it rarely lasts more than twenty-four hours at a time. When this wind blows from the southeast it brings with it sulphurous fumes, which are very oppressive, causing at times ophthalmia, cephalalgia, and dysentery, together with depression of spirits. The brutes are affected by it as well as man, and the grain wilts, as described in Pharaoh's dream. Happily the poisonous khamseen rarely lasts beyond sunset.

The harbor of Port Saïd is altogether artificial, there having been no natural protection for vessels here whatever. It consists of two basins, one lying outside and the other inside of the natural shore-line, the former protected by moles, the latter excavated in the sandy border of Lake Menzaleh.

The moles of the outer port are of unequal length and of very unequal importance. The western, which may be regarded as the windward mole, stretches out nearly at right angles to the original shore-line for a distance of 7,150 feet, then, deflecting to the eastward about twelve degrees, runs on 1,050 feet, to the twenty-six-feet curve of soundings as originally found. Ultimately this mole is to receive a further extension of 2,300 feet. Its general direction is northwest, and, as we have seen, its total length will be about two statute miles. The eastern mole

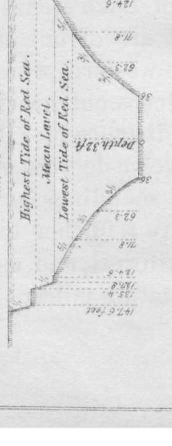
PORT SAID



SUEZ CANAL

Section at the Barrier of Chalouf

Furnished to the United States Coast Survey by the Compagnie Universelle.



AMSTERDAM CANAL

Section through the Dunes

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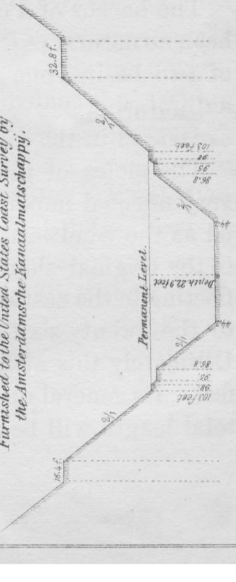

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is straight, and its course inclines towards the shoreward portion of the western mole about twenty-five degrees. Its direction is nearly north and its length is very nearly one statute mile. That the length of these moles may be appreciated, I give a tabular statement of other similar works designed to break the force of the sea.*

	Length in Feet.	Shelter in Acres.
Cherbourg Breakwater, 45 feet water	12,300	3,000
Holyhead, north pier	7,300	371
Portland, isolated breakwater	6,000	2,099
Plymouth (Eng.) "	5,248	1,853
Rochelle	4,482	
Aurigny	3,280	
Jersey, 2 moles	2,476	235
Dover (original design 10,591 feet)	1,800	
Venice, marble mole	4,600	
Marseilles (not finished), 52 feet of water	26,240	
Leghorn, isolated mole	3,700	
Genoa, new mole	3,900	
Algiers	2,500	221
Lion Bay (South Africa), 48 feet of water	26,240	
Palma (Majorca)	3,550	
Amsterdam, Canal Port, 2 moles, projected, each .	5,050	247
Delaware Breakwater and Ice-breaker	4,014	640
Buffalo, Lake Erie	1,452	
Alexander's mole at Tyre	3,500	

I could not learn what precise rules were followed at Port Saïd in the projection of the moles. It is obvious that the greater length and crooked course of the western is designed to cover the entrance from the northwest quadrant, but I do not comprehend why the main entrance to the inner basin should have been placed near this mole so as to have twenty degrees' rake of sea from the northeast. At the very time when a blow from the northeast makes the outer harbor unsafe, an escape to the inner harbor may be a dangerous experiment. It is, however, very rare that this outer basin is rendered even uncomfortable by storms. I have observed dredging-machines at work there during pretty strong northeast winds, and they did not seem to experience much trouble with their scows, etc.

Of the experience with the sands thus far I can speak with some confidence, as I was permitted to examine the several hydrographic surveys that have been made, and to compare them, make tracings, etc.

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* I omit piers designed simply to control the outflows of streams, some of which are, however, of great magnitude.

The long mole, by arresting the material travelling along the coast from the west, has caused a creeping out of the shore-line on the windward side. The space thus reclaimed is of triangular form, with an area of 378,000 square yards, and represents a filling of 622,000 cubic yards, for the eight years ending July, 1868. It is probable that this shore will advance till it reaches the end of the mole, and then the sands will sweep into or across the anchorage. To remove the amount of material thus annually brought in according to our figures would scarcely employ a good dredging-machine a single month in a sheltered spot; but beyond the harbor's mouth the work would assume a more serious character, and perhaps exceed in expense the farther extension of the mole.

Between March, 1860, and July, 1868, the advance of shore near the mole amounted to 1,213 linear feet, of which 350 feet was accomplished during the last eighteen months, and 88 feet during the last six months. During the last three years the advance has been in parallel bands, and it is evident, from the increase of base and depth, that the accumulation goes on in an increasing ratio. It is true that the amount for the final six months, to which we have referred, seems to decline a little, but Mr. Ritt (acting Director-General) informed me that in the other six months of the year a greater deposit might be looked for, because, according to his observation, the amount is greater after the season of flood, or during the last half of the year. This gentleman considers the Nile to be the source of these sands, and attributes them mainly to the outflow from Gemileh, the ancient Mendesian mouth of the river, six miles west of Port Saïd. If the shore-line continues to advance at anything like its recent rate, the dry land will extend to the extremity of the mole in about forty years. This visible extension of the shore does not, of course, represent all the filling that is going on, since there is maintained beneath the water a gentle slope, the foot of which is a long way out. In the results of studies of the submerged contours I do not feel much confidence, because experience has taught me to expect many unreal changes in comparing surveys made by different parties. I shall, however, give the most general and decided results that I have reached.

As the mole has been extended, there has been a tendency to deepen on the windward side near its extremity, but the hollow has been again filled up as the building continued. Accumulations have followed the mole, but have not appeared seaward of it, although considerable agitation of the more distant contours is unmistakable; and I think I am correct in stating that the amount of deposit under water is small in comparison with that represented by the advance of the shore-line, of which I have given the measurements. Between the surveys of 1860 and 1865, I consider the four fathoms' contour to have been unaffected by the mole. In the following year this contour was disturbed, as the mole neared the original three-fathom curve; and in 1867, although the mole did not reach a greater depth than three and a half fathoms at the time of the survey, the contours beyond were affected certainly as far out as the five-fathom curve. I conclude from these changes that the sands are agitated in deep water by the interruption which the mole offers to the waves and currents, and that practically it is impossible to carry the mole out to firm and unchangeable bottom.

Thus far I have spoken only of the accumulations to the windward of the great mole, which threaten the harbor; but I must now call attention to real injuries which have already occurred in the harbor itself from inroads of sand. I have already referred to the deepening which appears on the windward side of the great mole near its extremity, due to the *race* of the sea and coast current. Some of the material thus scoured away has been carried into the harbor, where it rests under the lee of the mole. It is probable that the amount of material thus supplied while the mole has been advancing will lessen now that the work is closed, because the *race* is now permanent in position instead of being, as heretofore, carried out into new ground continually. Moreover, the eastward deflection of the extremity of the mole seems to have a good effect in compelling the sands to dissipate themselves seaward.

Another and much more serious trouble has arisen from the driving of sands through the interstices of the mole itself.

These have actually destroyed the larger part of the channel first executed under the lee, so that the work has had to be done over in a new direction, and a portion of the harbor space abandoned. The full amount of deposits from this source I could not ascertain.

Both of the moles at Port Saïd are built for the most part of rectangular blocks of artificial stone, each over thirteen cubic yards in volume, and as these blocks are deposited *pell-mell* (I use the term technically) there occur, of course, large spaces between them, through which the fine sand is borne with each dash of the sea. In their haste to obtain the security and quiet which the shipping requires, the company omitted, in building this mole, the precautions usually taken. In pell-mell or *rip-rap* breakwaters (as they are sometimes called in this country), the English mingle different sizes of stones, so as to make the structure tight; the French attain the same end by first making a core of small stones and finally throwing over a covering of heavier ones. It is difficult to decide between the advantages offered by these two methods respectively. One may easily see that the English method consumes the greater mass of materials at the outset, and that by the wash of the sea a considerable waste must occur from the dropping out of all the small stuff that may be exposed. On the other hand, the voids being, theoretically, in a greater ratio to the mass in the French system, greater sinkage might be expected as the stones, grinding upon each other, lose their edges and angles. In practical experience, however, the sinkage, under similar circumstances of foundation and exposure, is found to be the same in both systems, and the final proportion of voids about twenty-eight per cent.*

The shore at Port Saïd is peculiarly favorable for construction in fascines, and I am convinced that jetties, like those just completed at the proposed new embouchure of the Meuse, would have been entirely successful. It is true that Egypt supplies little material for this kind of work; but in view of the loss which the company has sustained in repeated excavations, and in the permanent reduction of its mooring-space in the outer port, there can be little doubt that a saving could have been effected by the use of fascines, even if the material had been brought from a considerable distance.*

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* The method of building moles by tumbling blocks of stone into the sea is probably as old as maritime commerce. The Tyrians employed it long before Alexander's time, and traces of their work still exist to bear witness — albeit rather obscurely — to their skill and knowledge. The use of artificial blocks of stone dates back to the time of Vitruvius.

The tendency towards an accumulation of sand to windward is very much more favorable than the opposite tendency towards an encroachment of the sea, which is usually presented in the case of moles resting upon the shore. I conceive, however, that here, as at some other places where moles have been built, a direction might have been chosen for the structure that would have involved neither accumulation nor excavation,— the constructive and destructive tendencies being placed in equilibrium. The driving of sand through the mole does not excite anxiety among the engineers of the canal, because they conceive that it will cease as soon as a narrow strip of dry sand has formed under the lee, and that this narrow bank, being protected from the wash of the sea, will preserve a steep fore slope. I should fear, however, that in storms of great violence the sea would run up the low shore outside, spring over the breakwater, fall with violence upon the strip of beach, and spread the sands out over the channel. Again, I should fear that northeast seas, attacking the fore slope of this bank, would give it a very great spread or cut it up into shoals. I think it will be found necessary to cover this bank with a revetement of rubble or *fascinage*.

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* Upon the sandy shore of the German Ocean, the Dutch are building two remarkable harbors, in situations similar to Port Saïd, although more exposed to violent seas. One of these is the proposed new embouchure of the Meuse, and is to be the advance port of Rotterdam; the other is at the entrance to the new Amsterdam Canal. The former, built with fascines, has thus far withstood the sea better than the latter, the moles of which are built of beton blocks laid according to the system adopted at Dover, Spithead, and Plymouth. In comparing the two works, last year, I was struck with the absence of all trace of injury to the fascine work, and the very serious injury that the beton mole had sustained. The moving sands accumulate among fascines, and, by thus adding weight, give the structure great power of resistance when attacked by storm waves. Moreover, the flexible and rugged border of the fascine enables it to break up the wave, and thus consume its *vis viva.* The smooth beton block, on the other hand, not only fails to arrest the sands, but, offering a sudden obstacle to the wave, either starts from its foundation upon sudden attack, or, turning the sea, is undermined by the recoil. In the storm of 1825, when five hundred square miles of North Holland were submerged, the masonry portion of the outer dike at the Helder gave way, while the portion built with fascines remained uninjured.

I have already spoken of the beton blocks at Port Saïd as having a volume of thirteen cubic yards. This is not large for outside works. I observed none smaller, in actual course of deposit, at Leghorn, Genoa, and Marseilles; while at Civita Vecchia I found the convicts rolling over the fore slope of the island mole natural stones of twenty-eight cubic yards each. At Cette artificial blocks of fifty-two cubic yards (stones of this magnitude being deemed necessary to resist the waves) have been successfully tumbled into the sea. Heavy seas are rare upon the Mediterranean, yet at Algiers blocks of beton, measuring forty-eight cubic yards, if not bound together, were turned over by the waves while the moles were in progress.*

Pell-mell moles, especially those built of beton blocks, sink considerably (often three feet) not only from the grinding to which I have before referred, but also from the wear due to the siphoning of water through the voids. The blocks at Port Saïd are constructed of sand dredged from the harbor, mixed with the lime of Theil in the proportion of two to one. This lime, which is employed for beton almost everywhere upon the Mediterranean, is not too "energetic," so that the blocks dry slowly and homogeneously. They require three months of exposure to the dry atmosphere of Egypt before they can be safely tumbled into the sea. At the new advance port of Amsterdam the beton blocks are composed of one measure of Portland cement, four measures of dune sand, and five measures of gravel. Next to Portland cement the lime of Theil is the most successful of European mortars, but it is not equally durable in different localities. At Marseilles it remains pretty firm in the mole after twenty years' immersion, but at Havre it has failed. The longest trial of beton formed of this lime has been thirty years, and it has been found to soften very lately. The moles at Port Saïd are exposed neither to frosts nor high tides, but, on the contrary, lie in a generally quiet sea of pretty uniform temperature, so that they will remain firm till the experiment of the Ship Canal shall have been thoroughly tried. If success crowns the enterprise and the commerce with India and China chooses this route, of course these structures will be maintained even if material has to be sought in the uttermost parts of the earth.

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* Chevallier, *Cours de Travaux Maritimes*, 1866 – 67.

The area comprised between the two moles is four hundred acres, a space which, when properly excavated, will accommodate forty ships-of-the-line swinging freely at their anchors, or four hundred first-class merchant ships moored stem and stern. This exceeds the proposed accommodation at the new port of Amsterdam by nearly eighty per cent. There is, however, no berth to be found which is wholly *land-locked*, i. e. from which the open sea is not visible: and the wave " reductive power " as given by application of Stevenson's formula,* is scarcely thirty per cent. In this respect the harbor of Port Saïd is inferior to that proposed for Amsterdam; but it must be remembered that the shore of Holland is more exposed to heavy seas than the coasts of the Levant.

The inner harbor is reached by a pass through the beach six hundred and fifty feet wide, and the basin within (*Grand Bassin du Port*), although not wholly excavated, is of ample dimensions.

The city of Port Saïd has existed only since the commencement of the canal. Its aspect is not unlike some of our war settlements on the coast of South Carolina. It does not yet renew the splendors of Tennis, of which the ruined walls and baths lie a short distance off in Lake Menzaleh.† This new city is but an encampment of industrial representatives of the principal nations of the earth, mingled with stragglers from Eastern tribes. The contrast of complexions, costumes, and manners, added to the varieties of language and religious rites, makes a first meeting with the motley crowd very impressive. Upon a more intimate acquaintance the distinctions are found, on the whole, to be superficial, external rather than intrinsic. Those who form the rank and file are mostly of the vagabond class, whose want of character renders them essentially alike and tolerably harmonious. Nor does it appear that in the organization of labor a mixture of races involves complication. Among the excavators, the Orientals, who for ages have been essentially, when not nominally, slaves to their employers, are quick to learn the advantages and appreciate the justice of the contract system introduced by the Franks, and I found them in the dry diggings of the canal, working out claims, in organized gangs, like the miners in California. The number of Orientals and Europeans in the service of the company is about equal, and amounts to about twelve thousand. Much of the skilled labor is done by Greeks, who are somewhat more intelligent, and very much more wicked than the Arabs.* On the steam dredges and their tenders, Greeks, Italians, and Maltese predominate. These will be available as sailors when the work upon the canal ceases. Dr. Clot-Bey expressed in his history a conviction that the Arab is well calculated to become a sailor; but I doubt if he can ever be quite content to sail in Christian ships. The number of those who thus far have entered the foreign mercantile service is small.

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* Edinburgh Phil. Journal, 1853.

† Tennis, or Tenys, now a deserted mass of ruins, six miles from Port Saïd, was a flourishing city in the time of Cæsar Augustus, and its traditions claimed that it sprang up upon the ruins of a city of the Pharaohs. It must not be confounded with Tanis (the Zoan of Jeremiah) which lies on the other side of the lake.

At Port Saïd, and at other important settlements along the canal, the company has built hospitals, churches, and mosques; and everywhere the evidences of a wise regard for the workman's wants appear. In the relation of master and man, I observed neither arrogance nor insubordination. The Frenchman is democratic in his feelings and kindly in his bearing, but his discipline is nevertheless rigid and impartial. The foundries and machine-shops of Port Saïd are on a great scale, so that steamers will find the means of making repairs, and able machinists, at the very threshold of the canal and the sea. The city is supplied with Nile water, brought thither in pipes from the Fresh-water Canal.

In referring to my observations on the canal proper, I shall take for my text the following table, which was furnished to me by the Company.

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* I use the word "Arab" in its ordinary loose sense for Egyptians and their African and Asiatic neighbors. Strictly speaking, the Bedouin, who never works, is the true Arab. He does a little trading at times along the canal, but never yields any of his natural rights to the *Compagnie Universelle.*

Successive Points on Canal.	Width of Bed.	Width at the Water-line.	Width at the Plane of the Desert.	Total Height of the Banks above Water-line (Cavalier included).	Remarks.
Nautical Miles.	Feet.	Feet.	Feet..	Feet.	
0 to 0.43	....	....	....	....	Harbor of Port Saïd.
0.43 “ 0.48	180.4	436.2	436.2	5.9	Depth of Canal 26.2 feet.
0.48 “ 0.54	170.5	426.4	426.4	5.9	“ “ “ “
0.54 “ 0.59	150.9	406.7	406.7	5.9	“ “ “ “
0.59 “ 0.64	121.4	377 2	377.2	5.9	“ “ “ “
0.64 “ 0.70	85.3	341.1	341.1	6.5	“ “ “ “
0.70 “ 7.56	72.1	328.0	328.0	6.5	“ “ “ “
7.56 “ 8.64	72.1	328.0	344.4	4.9	Raz El Ech.
8.64 “ 9.72	72.1	328.0	328.0	9.2	Depth of Canal 26.2 feet.
9.72 “ 12.42	72.1	328.0	328.0	9.8	“ “ “ “
12.42 “ 13.50	72.1	328.0	328.0	11.4	“ “ “ “
13.50 “ 14.58	72.1	328.0	328.0	13.1	“ “ “ “
14.58 “ 21.00	72.1	328.0	390.0 to 433.0	6.5 to 16.4	“ “ “ “
21.00 “ 21.27	72.1	328.0	390.0 “ 442.8	6.5 “ 32.8	“ “ “ “
21.27 “ 25.27	72.1	328.0	390.0 “ 433.0	6.5 “ 16.4	“ “ “ “
25.27 “ 25.59	72.1	328.0	387.0 “ 472.0	6.5 “ 32.8	“ “ “ “
25.59 “ 29.59	72.1	328.0	390.0 “ 433.0	6.5 “ 16.4	“ “ “ “
29.59 “ 30.13	72.1	328.0	360.8 “ 393.2	6.5 “ 32.8	“ “ “ “
30.13 “ 32.61	72.1	328.0	390.0 “ 433.0	6.5 “ 16.4	“ “ “ “
32.61 “ 32.66	72.1	328.0 to 314.8	400.0 “ 360.8	6.5 “ 16.4	“ “ “ “
32.66 “ 33.42	72.1	314.8 “ 190.0	347.6 “ 236.0	13.2 “ 29.7	“ “ “ “
33.42 “ 34.12	72.1	190.2	206.6 “ 321.4	6.5 “ 36.0	“ “ “ “
34.12 “ 34.77	72.1	190.2	196.8 “ 321.4	9.8 “ 36.0	“ “ “ “
34.77 “ 35.31	72.1	190.2	196.8 “ 354.2	13.1 “ 26.2	“ “ “ “
35.31 “ 35.58	72.1	190.2	196.8 “ 308.3	16.4 “ 36.0	“ “ “ “
35.58 “ 36.61	72.1	190.2	216.4 “ 305.0	16.4 “ 32 8	“ “ “ “
36.61 “ 38.07	72.1	190.2	305.0 “ 370.6	29.5 “ 68.9	“ “ “ “
38.07 “ 38.88	72.1	190.2	370.6 “ 462.4	55.7 “ 108.2	Barrier of El Guisr.
38.88 “ 39.42	72.1	190.2	462.4 “ 269 0	108.2 “ 26.2	Depth of Canal 26.2 feet.
39.42 “ 39.74	72.1	190.2	269.0 “ 321.4	32.8 “ 45.9	“ “ “ “
39.74 “ 39.90	72.1	190.2	321.4 “ 242.7	39.6 “ 22.9	“ “ “ “
39.90 “ 40.28	72.1	190.2	242.7 “ 429.6	22.9 “ 49.2	“ “ “ “
40.28 “ 40.71	72.1	194.3	367.3 “ 308.3	59.0 “ 16.4	“ “ “ “
40.71 “ 42.22	72.1	Width of Lake Timsah.	....	No Banks.	“ “ “ “
42.22 “ 42.44	72.1	328.0	413.2	22.9	“ “ “ “
42.44 “ 42.66	72.1	Width of Lake Timsah.	....	No Banks.	“ “ “ “
42.66 “ 43.47	72.1	328.0	400.1	13.1	“ “ “ “
43 47 “ 45.09	72.1	328.0	373.9	6.5	“ “ “ “
45.09 “ 45.14	72.1	328.0 to 190.2	262.4	26.2	“ “ “ “
45.14 “ 46.76	72.1	190.2	314 8	59.0	“ “ “ “
46.76 “ 50.54	72.1	190.2	295.2	62.3 to 19.6	Barrier of Serapéum.
50.54 “ 50.59	72.1	190.2 to 328.0	275.0 to 393.6	32.8	Depth of Canal 26.2 feet.
50.59 “ 51.46	72.1	328.0	373.9	13.1	“ “ “ “
51.46 “ 51.62	72.1	328 0 to 656.0	373.9 to 820.0	13.1 to 6.5	“ “ “ “
51.62 “ 52.00	72.1	Lacs Amers.	....	6.5 one bank on African side.	“ “ “ “
52.00 “ 66.42	72.1	do	....	No Banks.	“ “ “ “
66.42 “ 68.04	144.2	do	....	(Cavalier submerged) 6.5 feet below.	“ “ “ “
68.04 “ 69.66	72.1	328.0 to 393.6	....	No Banks.	“ “ “ “
69.66 “ 70.74	72 1	360.8 “ 426.4	....	(Cavalier submerged) 3.2 feet below.	“ “ “ “
70.74 “ 71.82	72.1	410.0	492.0	13.1	Depth of Canal 32.8 feet.
71.82 “ 73.44	72.1	367.3	426 4	16.4	“ “ “ 31.7 “
73.44 “ 75.06	72.1	262.4	419.8	36.0 to 49.2	Barrier of Chalouf.
75.06 “ 76.14	72.1	223.0	410.0	49.2 “ 36.0	Depth of Canal 31.7 feet.
76.14 “ 84.24	72.1	301.7	367.3	16.4 “ 19.6	“ “ “ 29.5 “
84.24 “ 85.32	72.1	308.2	308.2	....	“ “ “ 29.5 “
85.32 “ 86.40	262.4	492.0	472.3	....	“ “ “ 29.5 “
86.40 “ 87.48	311.6	Roadstead of Suez.	426.4	Mouth of Canal.	“ “ “ 28.5 “

It must be borne in mind that the canal is without locks and gates, — indeed, without noteworthy masonry, — and that the elements given above are those of a great trench, dug partly by floating machinery and partly by hand labor. It will be observed that it passes through three natural barriers ("*seuils*"), at El Guisr, Serapéum, and Chalouf; and that between these barriers lie two ancient sea basins known as Lake Timsah and the Lacs Amers. By reason of the great expense that attended excavations through the barriers, the surface width was reduced at these three localities, but the width of the channel bed is nowhere less than seventy-two feet. The total amount of earth excavated may be set down at one hundred and four millions of cubic yards, which, taken in connection with the table of dimensions, shows that if the track followed had been a horizontal plane, its elevation would have scarcely exceeded that of the mean level of the two seas.

In traversing the first five miles of Lake Menzaleh I could see no decided variation in the material brought up by the dredge, although we crossed Linant's site of the ancient Tanitic branch of the Nile. Below the sands I call the material Nile mud which has undergone a "sea change," and has been converted into a sort of tough blue clay, like that which we frequently find in our harbors.*

At Ras El Ech, 7.8 miles from Port Saïd, where the true site of the Tanitic branch seems to be, the material becomes mostly mud, which crumbles into dust when exposed to the sun; yet even here lumps of hard material appear, which contain vegetable fibre, blue clay, shells, and corals.

Twelve to thirteen miles from Port Saïd the Pelusic branch of the Nile is reached, and here the surface soil may be at once recognized as Nile mud. It is above the level of the sea, and yet strata of salt testify to occasional overflows of sea water. In this locality I had no opportunity of examining the material from great depths. Twenty miles from Port Saïd I found portions of the lake, which are represented upon all maps as covered with water, dry and covered with salt, as with newly fallen snow. In this neighborhood the surface material resembles the mud of our salt marshes, and seemed to stand well above the water-line. I observed, indeed, that where the dredges had broken ground the moist soil, for heights of two to four feet, stood nearly perpendicular. Here there are dunes within a short distance upon the Asiatic side, and upon these, as well as upon the lower sands, occasional shrubs of tamarisk appear.

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* Mr. Taylor, Chief of the Bureau of the *Société des Forges et Chantiers de la Méditerranée* at Toulon, informs me that the Nile mud (which dissolves in fresh water) inclines to set in sea-water. He has experimented upon it. I have observed on the shores of Sandy Hook firm balls of clay rolling along the beach, and I am inclined to think that the clays of our shores undergo changes of consistency on reaching the sea. The blue clay of the Mississippi delta is met with at the mean level of the sea.

Near Kantara, twenty-three miles from Port Saïd, the canal leaves what may be properly called Lake Menzaleh, but after crossing a short reach of sand (the caravan track from Cairo to Syria) reaches another lake, or rather depression, for it only became a lake by the occurrence of a crevasse in the banks of the canal. The bed of this lies several feet below the level of the Mediterranean. Upon this lake are found the ruins of two cities, which probably flourished during the period when the Pelusic branch supplied fresh water to these basins. In leaving Lake Menzaleh the Nile muds and clays seem to disappear, and the material becomes loose sand, difficult to manage, especially in depressed basins. At a point thirty-three miles from Port Saïd, on reaching the dune country, the canal width is reduced to the minimum.

The portion of the canal I have thus far described is in many respects the weakest, because the banks of sand and mud are here and there inclined to slip; rubble-work and rude *fascinage* have been resorted to, however, with success.

I shall now pass on to the barrier of El Guisr, where a range of dunes forms a summit level between Lake Menzaleh and Lake Timsah.

The dunes in this portion of the desert are in motion, but this motion is somewhat superficial. In cutting through them, some horizontal strata of gypsum appear. I observed that one of these lay about three feet above the surface level of the Mediterranean, and was six inches in thickness. Except for these strata, the material would be of the worst description for banks. As it is, a rubble facing has been placed upon the slope at the water-line. As we have here a width at the canal surface of 190 feet, and a width at the bed of 72, with a depth of 26, we may consider the talus slope as 1 : 2.25 nearly, — a very steep slope to be maintained in sand washed by steamers' waves. In this section it is estimated that the winds drive into the canal 130,000 cubic yards per annum, i. e. a heavy month's uninterrupted work for a first-class dredge.*

In the neighborhood of this barrier are found traces of an ancient canal, called the canal of Necos — I do not know upon what authority. It appears to approach Lake Timsah from the northwest. Necos is credited by Herodotus with the first conception of a canal from the Nile to the Red Sea ; but it is very well ascertained that this was an error and that such a canal had existed many hundred years before. The grand achievement of Necos was the sending of an expedition from the Mediterranean to the Red Sea by way of the Cape of Good Hope, twenty-one centuries before Bartolomeo Diaz and Vasco de Gama.†

With a slightly increased section, the canal approaches and finally enters Lake Timsah abruptly at a distance of forty-one miles from Port Saïd. This lake, the name of which signifies *crocodile*, has been at some former period a fresh-water basin fed by the Nile. Vast deposits of river mud were found upon its dry bed when the engineers of the canal first traversed it. It was no doubt a reservoir for the ancient canal of the Pharaohs, which is still traceable. This canal, leaving the Pelusic branch of the Nile at the ancient Bubastis, near the modern Zag-a-zig, ran nearly due east through the land of Goshen into Lake Timsah, and thence to the Red Sea. Although it was reopened and renewed by subsequent rulers, — the Persians, the Ptolemies, the Romans, and even the first Caliphs,—there seems to be little doubt that this avenue of communication between the two seas existed in the time of Rameses II., when the children of Israel were preparing to leave the land of Goshen, where they had lived four hundred years.‡ The probability is that Lake Timsah had been the reservoir of irrigation for the land of Goshen a long time before even the Rameses ; because it is unreasonable to suppose that the engineers who conceived the splendid works of Lake Mœris and the Berket-el-Keroon, seven centuries before the Rameses, could have failed to recognize in the basin of Lake Timsah an admirable site for similar operations. The "pasture land" of Goshen, once the "best" of the land of Egypt, is now but a desert, nor can it be restored without again constructing a receiving-reservoir.* It is too far from the main stream and too far in the desert for any great supply of water to be maintained by a simple canal during the season when the river is low. In the project of the present Fresh-water Canal it was estimated that if all the water yielded by forty openings of the locks per day were devoted to irrigation in summer, it would answer for fifty-nine thousand acres, — a space smaller than the District of Columbia. This water, in the season when the river is low, has to be pumped up from the Nile and conveyed fifty miles before reaching the border of the land of Goshen.

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* Lecture of M. Lavalley before the Society of Civil Engineers at Paris, November 27, 1868.

† Rawlinson's Herodotus, App. Book II.

‡ Sir Gardner Wilkinson and Baron Bunsen agree in tracing the canal back to this Rameses. Lepsius regards this king and his immediate successor as the Pharaohs of Exodus.

The Fresh-water Canal, built by the present *Compagnie Universelle*, is essentially but a renewal of the ancient waterway of the Pharaohs, although it takes its rise farther west, in the main stem of the Nile. It communicates with Lake Timsah by locks. Along its track vegetation is rapidly reappearing, although, of course, the canal bears no great supply of sediment. But I observed, even where these fresh canal waters had become clear by filtering through the sand for a hundred feet, that their reappearance in the depressions beyond was followed by a heavy growth of rushes. The experience of those who have dug wells in the desert, from Moses down to Louis Napoleon, has been ever the same. In Arabia as in Algiers the soil demands only fresh water to clothe itself with verdure. It is difficult to conceive of natural causes which could have produced a great depression in the desert like Lake Timsah. There are at many points shallow basins which have evidently been hollowed out by the winds; but such cannot become deep, since the winds, bearing along only the fine sand, soon leave behind a sufficient quantity of flints to forbid further action.

In crossing Lake Timsah the canal has generally no banks, and yet the bed upon which the full depth is preserved is not enlarged. Vessels of great draught will find some difficulty in keeping in the channel during strong winds, — a difficulty which has been felt in the Caledonian Canal where it passes through the Scotch lochs. It is true that in the Caledonian Canal it is the sudden gusts from among the highlands that are troublesome when crossing the lochs, and these are not common in Egypt, where the breeze, though usually strong, is not fitful. It is the design of the Suez Canal Company to buoy and beacon the track thoroughly.

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* "And Pharaoh spake unto Joseph, saying, Thy father and thy brethren are come unto thee. The land of Egypt is before thee; in the best of the land make thy father and brethren to dwell; in the land of Goshen," etc. — Gen. xlvii. 5, 6. Again, in the same chapter, Joseph speaks of it as the "best of the land, the land of Rameses."

Lake Timsah is surrounded by a confused mass of dunes, which, to use the metaphor of Bremontier (applied to the Landes of France), resemble "*a sea in which the waves, in the fury of the storm, have become suddenly fixed,*" — as they might appear if seen by a flash of lightning at night. Farther off, in the more central part of this land of Goshen, where there are broad plains covered with flints, solitary dunes are seen like golden islands, and these are objects of grace and beauty in every detail. On near approach to one of them the sands may be seen travelling up the long rear slope before the wind, flying in the air at the crest, and falling down the fore slope in a perpetual cascade, — everywhere in motion, but preserving always the same faultless curves. Nor do these dunes leave a grain behind them to mark their tracks. The homogeneous sands of which they are composed are as fine as those we usually see in the hour-glass, and like the latter they serve to measure the lapse of time in their steady march.* In the neighborhood of Ismaïlia repeated measurements show that the advance is 98 feet per annum, — an unusually rapid rate. Bremontier, in 1780, stated the rate of the dunes of Les Landes at 65 feet per annum.† The prevailing winds in this portion of the desert blow from due north, and are more steady than at Port Saïd or Suez. In consequence of this the course of the dunes is so nearly parallel to that of the canal that their slow approach can always be prepared for. They can at any time be fixed by covering them with hedges of brushwood, but they can never be utilized like those of the Landes.

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* Deluc and Cuvier declare the dune to be a *véritable chronomètre.*

† In the Landes the inclination of the fore slope was found to be 50° to 60°, while that of the rear slope varied from 10° to 25°. See *Annales des Ponts et Chaussées* for 1833. The finest American dune that I have seen is at Cape Henlopen, which, although far inferior to those of Egypt, is really more perfect than any one I could trace in the now forest-clad Landes of France.

Lake Timsah is now a broad expanse of water covering nearly five thousand acres. The volume necessary to fill it was ninety-four million cubic yards, and this was led in from the Mediterranean through the canal, which at that time was but a ditch. The period required was five months, because it was found necessary to keep the velocity from rising above 0.59 mile per hour through the barrier of El Guisr, to prevent injury to the banks. Dubuat, from direct experiments in 1816, furnished a table of effective velocities of running water, in which he placed the rate which would move fine sand at 0.31 mile, and gravel the size of little peas at 0.34; he observed that a velocity of 0.60 caused grains of sand to move 6,560 feet in a year. Thomas Stevenson, in his work on harbors, gives a table compiled from different authors, in which 0.30 is given for lifting fine sand, and 0.39 for gravel as coarse as lint-seed; while to "sweep along fine gravel requires 0.59 mile per hour." T. Logan, in the proceedings of the Royal Society of Edinburgh, gives the details of recent experiments made by himself, in which he places the velocity required to move fresh-water sand at 0.41, sea sand 0.65, round gravel the size of peas 1.18 mile per hour. In calculating the resultant or scouring forces of tidal currents in our harbors, the Coast Survey has regarded all velocities below 0.33 mile per hour as ineffective, and has considered this velocity as just equal to the starting of grains of quartz sand. I see no reason yet to change these figures. Between the velocity necessary to *start* fine sand and that adequate to tumble down the banks of a canal in a serious or sensible manner, there must be considerable difference, — quite as much, perhaps, as the difference between 0.33 and 0.59; but Logan's result, 0.65 for sea sand, is certainly too large.

Leaving Lake Timsah, the canal traverses a series of little lagoons for about two miles with the full width of 328 feet, to the barrier of Serapéum, forty-seven miles from Port Saïd, and forty miles from the roadstead of Suez. In this locality are found the traces of ancient canals and the ruins of ancient settlements, indicating that here were once depots of commerce.

The barrier of Serapéum is far less formidable than that of El Guisr, but the width of the pass is here reduced again to 191 feet. The canal was dug dry to a certain extent, and then deepened by dredges, floated by water let in from the Fresh-water Canal. The engineers informed me that it would have probably cost less to dig it altogether dry, as at Chalouf, of which I shall speak hereafter. In this section there are extensive depressions below the level of the Fresh-water Canal, so that it was found convenient to flood these, and then deposit in them the material brought by scows from more elevated portions of the cut. The greatest elevation of the banks is about 62 feet. This is a dune section, yet the distinct traces of the ancient canal of the Pharaohs is found taking a course nearly parallel to the present maritime canal, and apparently passing with it into the Lacs Amers. But I am satisfied that the canal of the Pharaohs did not discharge into this ancient sea basin, since there are no traces of Nile mud and there is no evidence in history of its having made its terminus here. Probably it passed along the conveniently level border of this depression.

The Maritime Canal takes again its full width of 328 feet about a mile and a quarter before reaching the Lacs Amers, and enlarges gradually as it approaches the shore of the latter. I have already spoken of the tidal traces in the Lacs Amers, and of the shells strewn along their shores; I have now to call attention to the great area of the lakes, which is likely to prove an inconvenience. The depression consists of two unequal basins, the more northern having a length (northwest to southeast) of 13½ miles, and a maximum width of 6 miles; while the smaller basin, lying further south, has a length of about 6½ miles, and a width of less than 2 miles. The total area may be estimated at 100,000 acres.

In both of these basins great deposits of salt are found. The layer covering the bottom of the greater basin, which is upon the average from eight to ten feet thick, is estimated at sixty-eight millions of cubic yards, — a quantity equal to two thirds of the volume of earth excavated from the canal for the entire distance from the Mediterranean to the Red Sea. "As you descend into this basin you come first upon gypsum and other salts of lime, which, being less soluble, have been first precipitated, before the water shrank to the maximum saturation for the other salts." * It is probable that no portion of this deposit

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* V. Cadiat, *De la Situation des Travaux du Canal.* 1868.

was made during the period when this basin was visited daily by the tides of the Red Sea, since we know of no instance where tidal lagoons, however cut off from fresh-water feeders, precipitate salts, or even increase greatly in density. After the barrier (Chalouf) between this basin and the Red Sea had sufficiently formed to obstruct the tides, it is probable that at rare intervals it was broken or overflowed by the waters heaped up in the roadstead of Suez during southerly gales, so that the lake alternately dried up and partially refilled. In Lake Timsah, where at the time of my visit there was no tide, and where the single communication with the Mediterranean had been for the greater part of the year very contracted and much obstructed, the density of the water had advanced only from 1.026 to 1.043. With free communication between the two seas, not only will no more salt be deposited, but that which lies upon the bed of the Lacs Amers must be dissolved, because there will always be a movement through the canal. The mean levels of the two seas nearly correspond; but their temporary variations must be dissimilar. Winds which depress the sea at one extremity of the canal elevate it at the other, and the changes dependent upon the declinations of the sun and moon, as well as those dependent upon atmospheric pressures (barometric), cannot be equal or even coincident in the two seas.*

Over a large part of the great basin of the Lacs Amers the depth exceeds four fathoms, and the water volume of both basins combined is estimated at two thousand four hundred and eighty millions of cubic yards, without counting salts displaced by absorption. The major axis of the great basin lies about in the direction of the prevailing wind, so that it must be frequently subject to agitation. Indeed, by Stevenson's formula there should be at times waves five feet and a half in height. The canal entrance at the north end of the lake is usually under the lee, but in the spring it is not unlikely that it will sometimes be attacked by a sea capable of doing much mischief, not only by disturbing the banks of the canal itself, but also by rendering the ingress and egress of shipping unsafe. The little lake from which the canal passes on towards Suez is pretty well protected naturally. If vessels have occasion to come to anchor in the Great Basin, they must be provided with good ground tackle, for from the centre of it the land that offers them protection is seen but as a broken chain along the horizon, and the desert winds are strong. In the Little Basin of the Lacs Amers the canal has at some points submerged banks, which will be a source of trouble even if well marked, because to follow buoys and even dolphins through a channel only from 70 to 130 feet wide is a very perplexing task in windy and thick weather. The fogs were very dense in the morning during my stay in the desert, and this too while the Lacs Amers were still dry. In the sunlight the colors of the water will betray the position of the channel very exactly; and it is the intention of the company to build beacons every three hundred and thirty feet.*

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* I could obtain no positive information touching these changes in the two seas. The tidal observations had not been worked up for the purpose.

The canal makes a curve a little northward of the middle of the Little Basin, and here the company has very wisely given to the rocky bed an increased width of 144 feet, with banks of three to one up to the natural bed, which is here fourteen feet below the mean level of the sea. The work has of course been executed dry in this section, and beyond through the barrier of Chalouf.

Emerging from the Lacs Amers at a point seventy-one miles from Port Saïd (seventeen miles from the Red Sea), the canal still continues along a rather low portion of the desert for about two miles, in which space the profile of the section is peculiar. The upper slope is five to one, which may be set down as the slope of repose for dry sand everywhere in the desert where rains are inconsiderable. In this profile the slope of five to one continues to a point a little below the lowest tides of the Red Sea, then becomes horizontal, forming a berme about thirty-eight feet wide, beyond which the slope is increased to two to one and descends to the bed, which is over five fathoms below the mean level of the sea. The gradual slope for the perimeter of the tidal prism and the broad berme below are designed to anticipate the effect of a dissolution of some strata of salt which are exposed in the cut. One of these strata, about a foot thick, is seen like a layer of pure snow.

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* The training-wall of the Clyde is submerged at very high water, and is marked by beacons in this way.

At the barrier of Chalouf, seventy-four miles from Port Saïd (thirteen miles from the Suez roadstead), the banks rise fifty feet above the water level with a dry slope of 45°, at the foot of which a level terrace for a tow-path is constructed, about sixty feet wide, on either side. This terrace lies above the level of the highest tide of the Red Sea. The slope for the tidal prism is five to one, and below this there are two slopes of equal length, respectively three to one and two to one, stretching down to the bed, which lies over five fathoms below the mean level of the sea. The material met with in this barrier is principally clay and solid gypsum. Under the gypsum, at the depth of twenty feet below the sea-level, is a bed of freestone or grit, in which are found remains of marine animals, some of them extinct species. One of the laborers gave me a megalodon from this stratum. The excavation has been made by hand and the material carried up inclined planes by steam-power and deposited in cavaliers stretching back from the canal into the desert.

Leaving the barrier of Chalouf, the canal runs through a plain five feet above the mean level of the sea. For twelve feet above the bed of the canal the bottom is of hard shell rock with light coral intermixed, which at some points required blasting; above this is red shingle and the top sand; which sand, here as elsewhere, takes a slope of repose, five to one. The form of section referred to above for the Chalouf barrier is maintained. The height of the banks in the plain of Suez nowhere exceeds twenty feet. Through this plain and parallel to the line of the present Ship Canal ran the ancient canal of the Pharaohs. This canal was cleaned out for the last time by Amrou, who named it after his master, "Canal of the Commander of the Faithful." "It remained in this state one hundred and fifty years, until the reign of the Abbasside Caliph Abou-Jafar-el-Manzor, who in the year 159 of the Hegira (A. D. 781) ordered it to be closed at its outlet in the Sea of Kolsom" (Red Sea).* This canal, which has been dry eleven centuries, is still at several points in a remarkable state of preservation. As I rode along its bed and climbed its banks, I could scarcely believe that a single generation had passed since it was a pathway of commerce. In this portion of the desert, which is not traversed by dunes and is rarely washed by rains, all is changeless; your footprints remain in the soil till other footsteps obliterate them. One of my engineering friends picked up from the ground some pieces of silver and copper money which had not been current among men for fifteen centuries.

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* From Schems-Eddin, cited by Linant and Mongel in their report upon the original project of the present Ship Canal, 1855. Amrou actually proposed a direct canal from sea to sea.

After traversing the shallow lagoons for a distance of some six miles, the Maritime Canal enters the magnificent roadstead of Suez under the shelter of a handsomely paved rip-rap jetty. In approaching the sea, the section of the water-way enlarges, so that at its opening upon the roadstead the width at bed is 311 and the depth 28½ feet.

The Suez roadstead furnishes some land-locked anchorage berths, although the shelter to the southeast is distant and low. The holding-ground is perfect, — a light-brown clay. The Egyptian government has constructed dry-docks at the head of the roads after the most approved plans, and every facility for repairing and refitting ships will be found there and in the neighborhood. In spite of the absence of vegetation the scenery about the roadstead of Suez is very beautiful and grand. The sea has the rich blue of the bay of Naples, and the purple crags of Ghebel Attaka rise nearly three thousand feet upon the African shore.

Our information relative to the Red Sea generally is exceedingly meagre. The chart in use is from the survey of the East India Company, and is pretty good. From the reports of shipmasters, it would appear that northerly winds prevail to such an extent that sailing-vessels would find it difficult to work their way up to Suez. And yet we know that, previous to the discovery of the Cape of Good Hope in 1497, the Venetians and Turks had a considerable fleet of trading-vessels in this sea, and that the Portuguese sent a fleet in 1538 to destroy these vessels. I have no doubt that when the shores of this sea shall be properly lighted, its dangers marked by buoys and light-ships, and a better chart published, sailing-vessels will find their way up by taking advantage of occasional slants of wind, and of the current which, upon the lull of the north wind, sets up steadily, although feebly.

The channel is nearly everywhere over fifty miles wide, so that there is ample room for beating. The tidal currents do not seem to be either steady or strong, although there is a rise and fall of seven feet at Bab-el-Mandeb, and of five feet at Suez. In the central portion of this sea there appears to be as little tide as in the Mediterranean. The sky is clear nearly all the time, so that the latitude can be determined perhaps every day. The saving in distance between our ports and the East Indies by this new route is 3,200 miles *at least*, and over 4,000 miles upon the usual sailing-courses. The saving in time for outward-bound vessels will be in the same proportion; but for homeward-bound sailing-ships the route through the Suez Canal will consume more time than that round the Cape.

The Suez Ship Canal is the only one yet constructed without locks or gates, and it is the largest and deepest artificial waterway of any considerable extent that has ever been made. There are only three other long canals that claim to float first-class ships, viz., the Caledonian, the Great North Holland, and the new Amsterdam Canal.* The first of these is 52½ miles in length, with a bed 50 feet wide at the depth of 20 feet (maximum). The second is 42 miles in length, with a bed 31 feet wide at the depth of 20½ feet (maximum); and the third is 13½ miles long, with a bed 88½ feet wide at the depth of 23 feet. The surface width of the Amsterdam Canal is only 197 feet, so that its sectional area falls below that of the Suez Channel.

I have looked in vain through the entire history of this French enterprise in Egypt, to discover the least trace of earnest effort or sincere co-operation on the part of the Egyptian or Turkish government. I believe that the Viceroys of Egypt, from Mahomet Ali down to the present weak prince, have been coaxed into acquiescence by the master minds that conceived and executed this brilliant work, and I am convinced that this costly avenue, and the commerce employing it, will never be secure from interruption till the territory is neutralized or otherwise wrested from Mohammedan misrule.

HENRY MITCHELL.

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* The Vorn Canal in South Holland is but six miles in length, and the Saint Louis Canal, in the south of France, only *three*. Both of these are ship canals.

Navy, in Answer to a Resolution of the House, transmitting Correspondence relative to the Paraguay Difficulties.

Miscellaneous Documents, United States House of Representatives, No. 8, Pt. 2. Memorial of Porter C. Bliss and George F. Masterman.

6. Revue des deux Mondes; 1865, 1866, 1867.

7. Papeles del Tirano del Paraguay, tomados por los Aliados en el Asalto de 27 de Diciembre de 1868.

VII. CRITICAL NOTICES 544

Müller's Chips from a German Workshop, 544. — Bushnell's Women's Suffrage, and Mill's Subjection of Women, 556. — Nicolas's Quatrains de Khèyam, 565. — Friedrich Rückert and his Works, 584. — Baldwin's Pre-historic Nations, 594. — Kirk's History of Charles the Bold, 596. — Noeldeke's Alttestamentliche Literatur, 602. — Evans's Deutsche Literaturgeschichte, 606. — Publications of the Prince Society, 609. — Kinglake's Invasion of the Crimea, 612.

LIST OF SOME RECENT PUBLICATIONS 620

ERRATUM.

Page 488, line 2 from bottom, *for* northwest, *read* northeast.